Work, Energy and Power
Chapter 5
Work

- Work is done when a force causes displacement in the direction of the force
- W = F·d
- Unit is newton x meter = joule (J)
- A product of two parallel vectors that yields a scalar quantity, work
- Unlike the product of perpendicular vectors, force and lever arm that yields a vector, torque
- If force is at angle to displacement must find component of force in that direction
- $W = Fd(\cos\theta)$
- On graph of force vs. distance, work equals area under curve
- Work can be done against gravity, friction, spring, etc.

Power

- Rate of doing work
- P = W/t = F(d/t) = Fv
- Unit is watt (W) = J/s
- Often expressed as kilowatts (kW)
- English unit is horsepower (hp)
- 1hp = 746 W

Energy

- The ability to do work or move
- Two types of mechanical energy
  - Potential energy
  - Kinetic energy

Kinetic Energy

- Energy due to motion $K = \frac{1}{2}mv^2$
- Since velocity is squared, kinetic energy is always positive.
- To double speed, energy must be quadrupled

Work – Kinetic Energy Theorem

- Work done on object to change speed equals change in kinetic energy
- $W = \Delta K$
- Positive work increases speed, negative work decreases speed
- Kinetic energy of object equals amount of work it can do in coming to rest

Gravitational Potential Energy

- Stored energy due to position in gravitational field
- Equals work done to reach elevated position
- Must be referenced to some zero point

- $U_g = mg\Delta h$

Elastic Potential Energy

- Equals work done to stretch or compress spring or other elastic material
- Energy stored depends on stiffness of spring and distance stretched or compressed
- Spring constant, k (in N/m) describes stiffness
- Force from spring: $F = -k\Delta x$
- Negative sign shows force is in direction opposite Δx
- Energy stored in spring or work done on spring:
  $U_e = W = ½ F\Delta x = ½ k\Delta x^2$

Other types of Potential Energy

- Electrical and magnetic potential energy are due to position in electrical or magnetic field
- Chemical potential energy due to chemical composition of material

Conservative Forces

- Work done by conservative forces does not depend on the path taken: gravitation
- For conservative forces, total work done on closed path is zero.
- Conservative forces have no energy losses
- Example: lifting object from floor to table involves same amount of work no matter what route is taken. When returned to floor, same amount of work can be extracted.

Dissipative Forces

- Total work around closed path is not zero.
- Work done depends on length of path
- Main dissipative force is friction
- Dissipative forces cause energy loss as heat
- Work done against friction = force of friction times distance moved = energy lost to heat: $W_f = f_k\Delta d$

Conservation of Energy

- In a closed system with no dissipative forces, total mechanical energy remains constant
- Energy can change forms but can't be created or destroyed
- System must be closed: nothing enters or leaves

Examples of Energy Conservation

- Potential energy converts to kinetic when object falls, converts back to potential if it rises again: roller coaster or pendulum
- Energy stored in spring can convert to kinetic energy if used to launch object: catapult

Energy Conservation and Work

- Work input to system increases total energy by amount of work done
- Work done by system decreases energy by amount of work done
- With friction, change in mechanical energy equals work done against friction

Power and Energy

- Power in terms of energy is the rate energy is provided or the rate energy is used
- A 60 W light bulb transforms 60 J of electrical energy each second into thermal energy and light
- A 10 kW generator provides 10,000 J of energy each second

Vocabulary

- elastic potential energy
- gravitational potential energy
- kinetic energy
- law of conservation of energy
- work
- power
- conservative force
- dissipative force

Summary

- Work = displacement times force in that direction; unit is joule
- Work = area under force vs. displacement graph
- Kinetic energy is due to motion
- Power is rate of doing work or the rate energy is provided or used
- Gravitational potential energy is due to elevated position and equals work done lifting object.
- Elastic potential energy depends on force constant and distance spring is stretched.
- Conservation of energy means sum of all types of energy in closed system is constant.